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Homophone advantage in sentence acceptability judgment: An experiment with Japanese kanji words and articulatory suppression technique

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Abstract

The purpose of this study was to examine the role and nature of phonology in silent reading of Japanese sentences. An experiment was conducted using Japanese sentence acceptability judgment task. One important finding was that participants would more rapidly reject homophonic sentences in which one two-kanji compound word was replaced by its homophone word than non-homophonic sentences. In the latter, the word was replaced by a non-homophone spelling control; that is, we observed a homophone advantage. Participants were able to identify the correct word easily through foil's homophonic mate. This indicated that activated phonology played a role in the Japanese sentence acceptability judgment task and it contributed to the error detection/recovery process. Another important finding was that the homophone facilitation effect remained under articulatory suppression. It confirmed that phonology was activated at an early stage as abstract, non-articulatory phonology.

Key words: homophone, phonology, orthography, kanji, articulatory suppression

For more than a century, evidence has been accumulated on the role of phonology in silent reading. Most of them agree that phonological processing is involved not only in reading of a single word, but also when a word is embedded in a sentence or text (e.g., Baron, 1973; Coltheart, Avons, & Trollope, 1990; Coltheart, Laxon, Rickard, & Elton, 1988; Doctor & Coltheart, 1980; Johnston, Rugg, & Scott, 1987; Lee, Binder, Kim, Pollatsek, & Rayner, 1999; Newman, Jared, & Haigh, 2012; Rayner, Pollatsek, & Binder, 1998; Rayner, Sereno, Lesch, and Pollatsek, 1995; Treiman, Freyd, & Baron, 1983). However, the nature and the exact role of phonological processing in sentence reading has remained unclear. There are still some controversies regarding the effect of the writing system, the way phonological information is processed in a sentence, and the types of phonology, as we will discuss in the following sections. The current study aimed to clear these issues, using Japanese sentence acceptability judgment and articulatory suppression technique.

Feature of Japanese sentences

Written Japanese consists of kanji and kana scripts (see details in Kess & Miyamoto 1999; Leong & Tamaoka 1995; Tamaoka 1991; Tamaoka & Hatsuzuka 1997, 1998; Tamaoka, Hatsuzuka, Kess & Bogdan 1998). Kanji are so-called "logographic" characters of Chinese origin used to represent morphemes of spoken Japanese. The relationship between phonology and orthography seems to be significantly different for alphabetic language and kanji. Each kanji character has semantic as well as phonological value; that is, each character represents corresponding meaning(s), often having those suggested by visual shapes, and each character has its own pronunciation(s). It is important to note that any part of a kanji character does not directly correspond to phonological segments such as phonemes and that kanji-sound mapping is not strictly determined. The nature of the relationship between phonology and orthography is especially complicated in Japanese. It is, in fact, more complicated than Chinese, which has a similar logographic writing system (Hino, Kusunose, Lupker, & Jared, 2013), because most Japanese kanji characters have multiple pronunciations. In contrast, kana consists of written characters used to represent phonological units of morae. Kanji and kana appear mixed in a sentence. Although sentences are written without spaces between words in Japanese, the difference between kanji and kana often helps to divide a sentence into a word. In these respects, Japanese has very unique characteristics in the way it is written.

It has long been suggested that phonological activation would not typically arise in semantic processing of Japanese kanji (e.g., Saito, 1981). Although later studies have demonstrated phonological activation at an earlier stage in Japanese kanji processing (e.g., Morita & Matsuda, 2001; Sakuma, Sasanuma, Tatsumi, & Masaki, 1998; Wydell, Patterson, & Humphreys, 1993), its role and processing, especially in sentence reading, has not been perfectly understood. Even though a lot of studies in Chinese have been accumulated, they also showed some contradicting results. Some studies show evidence of very early phonological activation in Chinese (e.g., Perfetti & Tan, 1998; Perfetti & Zhang, 1995; Pollatsek, Tan, & Rayner, 2000), but others argue that orthographic processing is dominant over phonological processing (Feng, Miller, Sue, & Zhang 2001; Meng, Jian, Shu, Tian, & Zhou, 2008; Wang, Wu, & Chen, 2014; Wong & Chen, 1999). If we identify the role and nature of phonology in reading Japanese sentences, this will provide strong support for the inclusion of phonological processing in sentence reading and shed light on the role of phonology. Thus, we focus on the role and nature of phonology in reading Japanese sentences.

Phonological processing in sentence reading: Homophone interferes with the processing

To investigate the extent to which phonology is used during sentence reading, many studies have used sentence acceptability judgment tasks including homophones. In this task, a critical stimulus sentence is created, such that it can contain a word that has a homophone, followed by the correct word being replaced by its homophone mate. The rationale behind this was that if phonology activated the meanings of words, presentation of a homophone foil would activate both semantic representation of the presented word and the original correct word. Participants' reactions should be compared when one of the words is replaced by its homophone and the spelling control, which is not a homophone to the original correct word. Many studies in alphabetic languages have reported more false-positive errors for sentences containing homophones than for those containing non-homophonic spelling controls (e.g., Baron, 1973; Coltheart, Avons, Masterson, & Laxon, 1991; Jared, Ashby, Agauas, & Levy, 2016; Treiman, et al., 1983). For example, Coltheart, Avons, and Trollope (1990) showed that participants missed more foils in homophonic word sentences (e.g., The none says her prayers) than they did in non-homophonic word sentences (e.g., The nine was in church). It has been assumed that a higher false acceptance rate for sentences with a homophone foil than a spelling control foil is an indication that phonological representations were activated. If readers activated the meanings of words using phonology, then homophone errors would be harder to detect than spelling control errors. These findings have been extended to pseudohomophones (i.e., non-words that make the sentence sound correct, Patterson & Coltheart, 1987). The same effect has also been found in a paradigm closely related to phrase evaluation and proofreading. Participants miss more errors that preserve the phonology than those that violate the phonology. The effect is obtained both with homophones (e.g., Daneman & Stainton, 1991) and pseudohomophones (e.g., Van Orden, 1991).

A body of research focusing on eye movements has also investigated phonological processing using homophonic sentences. Many of these studies have shown that homophone foils in a sentence get shorter fixation times than non-homophone spelling controls (e.g., Jared, Levy, & Rayner, 1999; Pollatsek, Lesch, Morris, & Rayner, 1992). It has been suggested that readers activate the phonology of the homophone and then activate the meaning of its context-appropriate word. For example, Rayner, Pollatsek, and Binder (1998) reported that participants hardly realized the homophone foil especially when the homophone was visually similar to the context-appropriate word and the context was highly constrained. The phonological involvement in sentence reading has also been demonstrated in logographic language (e.g., Liu, Inhoff, Ye, & Wu, 2002; Pollatsek et al., 2000; Tsai, Lee, Tzeng, Hung, & Yen, 2004).

In sum, these studies of reading tasks indicate that phonological information is available in sentence reading, and the phonology generated from homophone words can activate the corresponding meaning of contextually appropriate words. It usually results in participants mistakenly using the meanings of the words.

Homophone facilitation effect: Error recovery

Some studies using proofreading tasks have supported this idea, though the results were not exactly the same as those for sentence acceptability judgment (Daneman & Stainton, 1991; Daneman, Reingold, & Davidson, 1995). Not only were participants less likely to notice homophone errors in proofreading, they were also faster in repairing the homophone errors as compared to the non-homophone control errors. It has been assumed that participants will be able to identify the correct word easily through foil's homophonic mate. Although it sometimes leads to failure of detection, it is easier to repair if the error can be detected because the correct unseen homophone has already been activated. The presence of this error recovery process was supported by some studies using the error disruption paradigm (Daneman & Reingold, 1993; Feng et al., 2001; Rayner et al., 1998). Feng et al. (2001) showed that English readers were initially misled by phonology within the first fixations. However, readers discovered the mismatch in orthography and made quick corrections on the error words. This leads to a homophone benefit in error recovery. It means that phonology may have effects that begin very early during the normal reading of English text, as its effect was confined only to the first fixation duration. In addition, they did the same experiment with Chinese readers. They found the homophone benefit in Chinese too, but interestingly, they found no evidence for early phonology in Chinese. In sum, these studies suggested that homophones could play advantageous and disadvantageous roles in sentence processing. The advantage seems to be related to later phonological activation and the disadvantage to be related to earlier processing. These phonological processing might differ depending on the writing system.

In fact, some Japanese sentence-reading task studies found that there are benefits of using homophones and that no homophone interference is present in sentence-reading or proofreading tasks.

Matsuda (1991) showed that pseudohomophones in sentences were easily detected during Japanese text proofreading. In this study, the participants were given stimulus sentences that were typed out on paper and then asked to detect errors in spelling. There were incorrect words that were homophones of correct words (pseudohomophones) and some that were not homophones (non-words). For example, when the correct word was 食堂 (/syoku doR/, meaning "dining room"), 食動 (possibly pronounced as /syoku doR/) was used as its pseudo-homophone and 食頻 (possibly pronounced as /syoku hiN/) was used as its non-word. Participants detected a greater number of pseudohomophones as incorrect than non-homophonic non-words; that is, they missed less pseudohomophones than non-homophonic non-words. This effect was also observed in Japanese sentence acceptability judgment task (Morita & Tamaoka, 2002) and in the proofreading task (Morita & Tamaoka, 2002; Shimomura & Yokosawa, 1993), with sentences that included a pseudohomophone. A possible explanation of this homophonic facilitation is as follows: To reject the sentences including a foil correctly, it might be an efficient way to identify the original word, from which the foil was generated. It is likely that phonological and contextual information of the foils could help activate the original word. A pseudohomophone might activate the original contextually appropriate word faster than a non-homophonic non-word. Consequently, correct rejection times for a pseudohomophone sentence could be faster than the same for a non-homophonic non-word sentence.

In other words, phonological activation occurred in reading Japanese sentences but the error recovery process would occur before participants made the judgment. In the case of Japanese pseudohomophones, they may be relatively easy to repair due to the involvement of orthography. It has been argued that orthography has a relatively larger influence in Japanese kanji word recognition tasks than it does in those using alphabetic writing systems (e.g., Sakuma et al., 1998; Wydell et al., 1993). Furthermore, Japanese readers tend to pay more attention to homophonic errors due to being exposed to a large number of homophonic words in Japanese. For example, when Japanese people write a kanji word with a keyboard, they input its pronunciation by kana or by alphabet (for example, "ka-n-ji") and try to convert it into kanji (for example, "漢字"). Then, they select correct kanji from many alternatives in conversion (for example, "漢字," "幹事" "監事," all pronounced /ka-N-ji/). Due to this situation, Japanese readers often encounter homophone errors in Japanese texts generated by word processors. Therefore, they might tend to be aware of the misspelling of the homophonic errors before they respond incorrectly on a sentence verification task, reducing the possibility of false positive responses to sentences with a homophone foil.

Thus, the direction of the homophone effect would depend on how rapidly the misspelling is detected. However, this homophonic facilitation effect in the Japanese sentence-reading task has so far been found only in the studies using pseudohomophone. The facilitation might be explained by the fact that the foil was a non-word (maybe because its orthography is not familiar), instead of the feature of Japanese kanji or a Japanese sentence. Thus, the main purpose of this study is to confirm that a homophone word facilitates sentence acceptability judgment.

The type of phonology included in Japanese sentence reading

The argument about phonological processing in sentence reading is not restricted to its occurrence.

In terms of the nature of phonological representation, there are at least two types of phonology, demonstrated in many studies using the articulatory suppression technique. One is speech-like or articulatory phonology, and the other is the abstract or non-articulatory type (Baddeley, Eldridge, & Lewis, 1981; Besner & Davelaar, 1982; Eiter & Inhoff, 2008; Frost, 1998).

An increasing number of studies now focus on the nature of speech-like, articulatory phonology (Clifton, 2015., Leinenger, 2014). Some studies propose that articulatory phonology activated during sentence reading contains not only segment information about phonemes, but also suprasegment information such as syllable structure (e.g. Ashby, 2010; Ashby & Rayner, 2004; Carreiras, Vergara, & Barber, 2005; Fitzsimmons & Drieghe, 2011), or readers' accents (Filik & Barber, 2011). In contrast, it has long been thought that lexical phonology is abstract and non-articulatory in nature. Besner (1987) indicated that phonological processing with respect to lexical access of English words seems to be non-articulatory; that is, it is not susceptible to interference from articulatory suppression (see also Besner & Davelaar, 1982). The existence of these two types of phonology is also supported by Taft (1991), showing that articulatory suppression did not exert an influence on the judgment of whether an exemplar of a certain category was included in a presented sentence, but rather influenced the judgment of whether a presented sentence was an acceptable sentence or not. Taft (1991) suggested that the latter task was susceptible to articulatory suppression because it required more reliance on working memory. More recently, Tree, Longmore, and Besner (2011) re-examined the effect of articulatory suppression and concluded that it had an impact on segmentation and on the phonological/orthographic comparison process. Jared et al. (2016) also investigated the effect of articulatory suppression on homophone effect in

Grade 5 students. They showed that the homophone effect was smaller with articulatory suppression than with tapping, which means that articulatory suppression impaired the use of a phonological code. However, sentences with homophone errors were still harder to detect than those with spelling control errors even with concurrent articulation. They suggested that Grade 5 students could generate a phonological code automatically. In fact, previous studies with Japanese kanji stimuli also showed that articulatory suppression did not have any influence on the homophone interference effect in semantic judgment tasks (e.g., Morita & Saito, 2007).

As mentioned in the previous section, homophone advantage and disadvantage might derive from different processing stages. The disadvantage is assumed to be related to a very early phonological activation, whereas later phonological processing seems to help error recovery and result in the homophone advantage. Articulatory suppression would not interfere with early phonological processing, as many studies of word recognition have shown (e.g., Baddeley & Lewis, 1981; Besner & Davelaar, 1982; Besner, Davis, & Daniels, 1981). However, we have not found convincing evidence about the late processing. Some studies showed that articulatory suppression had no interference on obtaining the general meaning of a sentence (Baddeley et al, 1981; Levy, 1978) but interfered with late phonological processing for combining concepts or for integrating information (Slowiaczek & Clifton, 1980).

The current study used the articulatory suppression technique to determine the type of phonology activated in Japanese sentence reading. This is the first experiment to examine the type of phonology giving rise to the homophone effect in Japanese sentence reading. If the homophone effect is caused by non-articulatory phonological activation of a word, then articulatory suppression would have no influence on the size of the homophone effect. In contrast, if the homophone effect is caused by articulatory phonology, like the inner voice, articulatory suppression would diminish or reduce the homophone effect. Especially, if homophone facilitation occurs in Japanese sentence acceptability judgment, the type of phonological processing might be different from those in the sentence processing of a sentence written in alphabetic language. We examined which of the phonology would cause the homophone facilitation effect.

Method

Participants

Thirty-six Japanese graduate and undergraduate students (23 females and 13 males) participated in the experiment. The average age of the participants was 21 years and 7 months. Half of the participants were assigned to silent condition, and the other half to articulatory suppression, randomly.

Design

The experiment used a two (homophony: homophone and non-homophone) by two (articulatory suppression: silent and with articulatory suppression) factorial design. Homophony was manipulated within participants, and articulatory suppression was manipulated between participants.

Apparatus

Each pair of stimuli was presented to participants on a display (EIZO) connected to a personal computer (Oteck Idaten Neo-i 7500X). The “M” key (indicated by a blue seal) and the “Z” key (indicated by a red seal) on the keyboard were used for responding. The presentation and recording of the participants' responses and their response times were controlled by SuperLab.

Task

The task was sentence acceptability judgment. The participants were asked to judge whether a presented sentence was meaningful or not.

Stimuli

The 32 sentences were used as the original sentences for the unacceptable sentences. A pilot experiment was conducted to control predictability for the original target stimuli of foils in sentences. First, we prepared a list of 64 Japanese sentences, each including one of the target words. The 64 target words were adopted from the two-kanji compound words used in Morita and Saito (2007). Each sentence was 19 - 33 characters long and included more than two 2-kanji compound words, one of which was a target word. For example, "赤，青，黄など彩度の高い国旗の色調は，とてもよく目立つ" means, “The colors of national flags with high chroma are particularly noticeable,” in which chroma (彩度) is a target. In the pilot experiment, each target word was replaced with blanks (□□), for example, “赤，青，黄など□□の高い国旗の色調は，とてもよく目立つ,” and participants were required to fill in the blank areas of the 64 sentences, which were presented on a piece of paper. Forty-six Japanese undergraduate students were given the sentences. The percentage of participants who could write the original target word was calculated for each sentence. We selected 32 of the 64 pairs of sentences that had relatively high predictability, because we attempted to investigate the homophone effect in sentence reading. If the target was not predictable from the context, the effect of the context would decrease. The mean predictability (the percentage of participants who wrote the target word) of sentences was 49.0 % (13.3%–89.1%, *SD* = 22.5).

One two-kanji compound word was replaced by a homophone or non-homophone foil. The example stimuli are presented in Table 1. In the 32 homophone sentences, the foil was a homophone of the correct word, that is, the sentences sounded acceptable. For example, in the original sentence "赤，青，黄など彩度の高い国旗の色調は，とてもよく目立つ," the word "彩度" is pronounced /saido/ meaning "chroma." In the homophone sentence, however, "彩度" was replaced by "再度," which is also pronounced /saido/, although it means "again." In the 32 control non-homophone sentences, the foil was a non-homophone, that is, it was not acceptable phonologically or orthographically. For example, in the non-homophone sentence, the original "彩度" was replaced by "制度," which is pronounced /seido/ and means "system." There were some restrictions in preparing these stimuli. First, the original words and their corresponding homophone foils had the same accent pattern. Second, there was no homophone two-kanji compound word more familiar than the original word and its homophone foil. Third, psycholinguistic variables of homophone and non-homophone foils were controlled (Table 2). The average word frequency (calculated from Amano & Kondo, 1999) were controlled between homophone and non-homophone foils in orthographically similar condition and in dissimilar condition separately (t (15) = 0.014, p = .989; t (15) = -0.013, p = .990, respectively). The average number of words morae were also compatible between homophone and non-homophone foils in the two conditions (t (15) = -1.000, p = .333; t (15) = 0.000, p = 999, respectively). The average number of strokes were not significantly different between the conditions (t (15) = 1.518, p = .150; t (15) = 1.834, p = .087, respectively).

Although the average number of strokes of homophone foils tended to be larger than that of non-homophone foils, this is the conservative stimulus structure for the test of our assumption. That is, we predict homophone foils are processed faster than non-homophone foils while the larger number of strokes potentially slows the processing speed.

We also prepared orthographically similar and dissimilar foils in order to control the orthographic similarity since some previous studies suggested that the contribution of phonology was different depending on the orthographic similarity. Half of the 32 unacceptable sentence sets included orthographically similar foils, that is, the originals, their homophone foils, and their non-homophone foils shared either of the kanji of a two-kanji compound (Table 1). In half of these 16 sets, the original words, their homophone foils, and their non-homophone foils shared the left member of the two-kanji compound, while in the other eight sets, the original words and their two types of foils shared the right member of the compounds. The other half of the 32 sets included orthographically dissimilar foils, that is, the original words, their homophone and non-homophone foils did not share any members of the kanji compounds. The frequency and the number of strokes could not be controlled between the orthographically similar foils and the dissimilar foils (Table 2) due to the difficulty in controlling for all psycholinguistic variables among four conditions derived from the two (homophony) by two (orthographic similarity) stimulus structure. We prioritized the strict control of the variables for the test of the homophone effect in accordance to the purpose of the current study.

These 32 sets were used only in negative trials, and as such, their originally correct sentences were not presented to the participants. They were presented with eight sentences including an orthographically-similar homophone foil, eight including an orthographically-dissimilar homophone foil, eight including an orthographically similar non-homophone foil, and eight including an orthographically dissimilar non-homophone foil. Homophone foils and non-homophone foils shared the same context (i.e., they were from the same sentence sets). Thus, the location of the foil (number of characters ahead of the foil) was the same between these two homophony conditions in each of two orthographic similarity conditions (Table 2). Each participant was presented with only one of the foils for each sentence. However, orthographically similar and dissimilar foils did not share the same context (i.e., they were from different sentence sets) and the place of the foil was not controlled. This is because it was almost impossible to prepare the same context for all of four conditions derived from the two (homophony) by two (orthographic similarity) stimulus structure (Table 2). We prioritized the strict control for the test of the homophone effect in accordance to the purpose of the current study.

To avoid presenting the same context twice to any participant, the experiment employed a cross-counter design. Thus, 16 homophone sentences and 16 non-homophone sentences were presented to each participant. In addition to these unacceptable sentences, we prepared 32 acceptable sentences for filler trials. As for the unacceptable sentences, each acceptable sentence was between 19 and 33 characters long and included more than two, two-kanji compound words.

Procedure

All participants were tested individually. In each trial, the participants were first presented with a "***" as a sentence start point. The duration of the fixation point was 200 ms, followed by 300 ms of a blank display. Next, a sentence was presented until the participant made a response. The time between a sentence presentation and a participant's response was recorded as the response time. Participants were instructed to decide as quickly and accurately as possible if the sentence made sense. They were asked to press the blue ("M") key if they thought the sentence was acceptable, and to press the red ("Z") key if they thought the sentence was not acceptable.

The experimental session was divided into four blocks of 16 trials. The participants in silent condition did these judgments silently. In articulatory suppression condition, the participants were asked to repeatedly say "1, 2, 3" aloud in Japanese at approximately the rate of one utterance per second throughout each block. Before the training trial, participants practiced saying "1, 2, 3" at a consistent rate. This method of articulatory suppression has been shown to be quite effective at least in a Japanese Kanji serial recall task, where suppression reduced recall performance more than 25 percentage points and removed phonological similarity effects completely (Saito, Logie, Morita, & Law, 2008). These four blocks followed training trials that contained eight acceptable sentences, four homophone sentences, and four non-homophone sentences.

Results

Only correct responses were used to calculate the mean response times. Before performing the analyses, response times more than two *SD* above or below a participants' mean were removed from the following analyses. 2.7 % of the total responses of the 36 participants, fell into this category.

The results in orthographically similar and dissimilar conditions were analyzed separately. Although the characteristics of foils and sentences were carefully controlled between the two homophony conditions, those were not matched between the two orthographic similarity conditions. Therefore, it is not appropriate to compare the orthographically similar and dissimilar conditions directly.

Orthographically similar condition

The mean response times in orthographically similar condition are presented in Figure 1. A two-way ANOVA (analysis of variance) revealed that a main effect of homophony was significant in subject analysis (F_1 (1, 34) = 16.096, p <.001, MSE = 203382.941, partial η^2 = .321), and in item analysis (F_2 (1, 30) = 4.877, p = .035, MSE = 695252.094, partial η^2 = .140). The participants took longer in responding to non-homophone sentences than to homophone sentences. A main effect of articulatory suppression was not significant (F_1 (1, 34) = 0.134, p = .717, MSE = 876266.069, partial η^2 = .004; F_2 (1, 30) = 2.801, p = .105, MSE = 208496.731, partial η^2 = .085). An interaction between and homophony and articulatory suppression was not significant (F_1 (1, 34) = 2.700, p = .110, MSE = 203382.941, partial η^2 = .074; F_2 (1, 30) = 0.403, p = .530, MSE = 208496.731, partial η^2 = .013).

The mean error rates are presented in Figure 2. A two-way ANOVA revealed that a main effect of homophony was not significant (F_1 (1, 34) = 2.152, p = .152, MSE = 488.154, partial η^2 = .060; F_2 (1, 30) = 0.926, p = .343, MSE = 1007.716, partial η^2 = .030). A main effect of articulatory suppression was marginally significant in subject analysis (F_1 (1, 34) = 2.873, p =.099, MSE = 365.605, partial η^2 = .078), and significant in item analysis (F_2 (1, 30) = 5.000, p = .033, MSE = 186.728, partial η^2 = .143). The participants in articulatory suppression condition tended to make more errors than in silent condition. An interaction between homophony and articulatory suppression was not significant (F_1 (1, 34) = 0.018, p =.895, MSE = 488.154, partial η^2 = .001; F_2 (1, 30) = 0.041, p = .840, MSE = 186.728, partial η^2 = .001).

Orthographically dissimilar condition

The feature of Japanese kanji words allows us to use homophones that have totally different orthography. The mean response times in orthographically dissimilar condition are presented in Figure 3. A two-way ANOVA revealed that a main effect of homophony was significant in subject analysis (F_1 (1, 34) = 27.566, p <.001, MSE = 292418.281, partial η^2 = .448), and marginally significant in item analysis (F_2 (1, 30) = 4.071, p = .053, MSE = 1425735.428, partial η^2 = .119). Again, the participants took longer in responding to non-homophone sentences than to homophone sentences. A main effect of articulatory suppression was not significant in subject analysis (F_1 (1, 34) = 1.942, p = .173, MSE = 1308353.466, partial η^2 = .054), but significant in item analysis (F_2 (1, 30) = 7.276, p = .011, MSE = 199824.881, partial η^2 = .195). Although the participants in the articulatory suppression condition tended to take longer than those in a silent condition, there may have been a large individual difference in the RT. An interaction between and homophony and articulatory suppression was not significant (F_1 (1, 34) = 0.099, p = .755, MSE = 292418.281, partial η^2 = .003; F_2 (1, 30) = .0201, p = .657, MSE = 199824.881, partial η^2 = .007).

The mean error rates are presented in Figure 4. A two-way ANOVA revealed that a main effect of homophony was not significant (F_1 (1, 34) = 0.576, p = .453, MSE = 184.462, partial η^2 = .017; F_2 (1, 30) = 0.086, p = .771, MSE = 1093.493, partial η^2 = .003). A main effect of articulatory suppression was significant (F_1 (1, 34) = 6.663, p =.014, MSE = 547.513, partial η^2 = .164; F_2 (1, 30) = 19.059, p < .000, *MSE* = 170.139, partial η^2 = .388). The participants in articulatory suppression condition made more errors than those in a silent condition. An interaction between homophony and articulatory suppression was not significant (F_1 (1, 34) = 1.424, *p* =.241, *MSE* = 184.462, partial η^2 = .040; F_2 (1, 30) = 1,372, *p* = .251, *MSE* = 170.139, partial η^2 = .044).

Discussion

The exact role and the nature of phonology in sentence reading still remains controversial. We examined the homophone effect in silent reading of Japanese sentences including kanji words. Japanese kanji words can have multiple homophones, and Japanese sentences usually contain both kanji and kana characters. These characteristics of Japanese kanji might cause homophone facilitation effect. We further examined the type of phonology that caused the homophone effect.

Homophone facilitation effect

One of the purposes of the current study was to confirm that homophone facilitation effect would occur in Japanese sentence acceptability judgment. First, the results of RT generally showed a homophone effect. The finding that the unseen homophone mate had an impact on the judgment, is the evidence that the representations of this homophone mate were activated. It indicates that phonological processing of a word is included in Japanese sentence reading. Such results are consistent with the findings of many previous studies in alphabetic languages using sentence judgment tasks (Baron, 1973;

Coltheart, Avons, Masterson, & Laxon, 1991; Coltheart, Avons, & Trollope, 1990; Treiman et al. 1983), and non-alphabetic language studies (Liu et al., 2002; Pollatsek et al., 2000; Tsai et al., 2004). Second, and more importantly, we observed a homophone facilitation effect rather than a homophone interference effect. Participants reacted to homophonic sentences more rapidly than to non-homophonic sentences. The direction of this effect was different from that reported in most sentence acceptability judgment studies undertaken with alphabetic languages (e.g., Coltheart, Avons, & Trollope, 1990). Generally, it is more difficult to reject a homophonic sentence than to reject a non-homophonic sentence. Readers usually miss more homophones than non-homophonic spelling control words. The higher false acceptance rate for homophonic sentences than non-homophonic sentence indicates that phonological representations were activated. In contrast, some proofreading studies or error disruption paradigms, even in alphabetic language studies, found this homophone advantage (Daneman & Stainton, 1991; Daneman, Reingold, & Davidson, 1995). Homophone facilitation has been assumed to occur because it is easy to repair if the error is detected when the correct unseen homophone has already activated. Our results support this explanation. As in the previous studies, the results of reaction time showed the homophone facilitation effect in the current experiment. The speed for repair would be facilitated when the foil was a homophone compared to when the foil was a non-homophone. Similar to the study of Feng et al. (2001) who showed that homophone errors were more easily recovered than non-homophone errors, recovery would happen in later processing stages, not in very early activation. In the later error recovery process, readers resorted to all available cues to recover the meaning, and phonology would be the most useful sources. Feng et al. (2001) pointed out that the use of phonology would be universal. Our results here could not determine whether very early phonological activation occurred or not, but at least, we showed that the error recovery process would sometimes occur before participants made the judgment. It might be because orthography of Japanese kanji would also be helpful in the error recovery process. One possible and persuasive reason of this sensitiveness would be that Japanese words often has multiple homophones.

In addition, we found that this homophone facilitation effect was significant even when the presented homophone did not share visual characteristics with an unseen, context-appropriate homophone mate. This finding provides evidence that the context-appropriate homophone mate can be activated when a sentence includes a homophone error, even if the presented homophone and its mate have no orthographic overlap. This result is different from previous semantic decision studies of Japanese two-kanji compound words, which observed a homophone effect only when the homophone pair was orthographically similar (Sakuma et al., 1998; Wydell et al., 1993). These studies suggested that both orthography and phonology contribute to activation of word meaning, though the orthography has a stronger effect on kanji word recognition. Although the results of this experiment apparently contradicted these previous studies, we do not have to reject their view. The difference between previous studies and the current experiment can be explained in terms of task differences. Given that the reaction times in the present sentence judgment task were much longer than the word decision task, the meaning of the context-appropriate word had already received sufficient activation from the phonological representation of the homophone foil in the present sentence judgment task. In addition, some other word decision studies showed a homophone effect even when the words were orthographically dissimilar. Hino et al. (2013) showed that orthographic similarity had no impact on the size of the homophone effect, though their task was lexical decision.

In sum, the current experiment demonstrated a homophone effect even when the homophone foil was orthographically dissimilar to the contextually appropriate word. This result strongly supported that phonology is included in Japanese silent reading, regardless of whether orthography is helpful for performing the task or not. An important finding here was that the direction of the effect showed homophone facilitation, which would indicate that Japanese readers are sensitive to the orthography of kanji words and recover the error.

Articulatory suppression effect on homophone effect

Another important purpose of this study was to investigate the type of phonology that brings homophone effect in sentence reading.

The results showed that articulatory suppression increased the error rate in the sentence acceptability judgment, regardless of the type of foil. It was true not only for the unacceptable sentences but also for the correct sentences, i.e., the filler sentences. The error rate for these filler sentences was significantly higher in articulatory suppression (9.7%) than in silent condition (3.8%). Although there seemed to be some trade-off in orthography dissimilar condition, the results generally showed that sentence acceptability judgment was more difficult under articulatory suppression. As Slowiaczek and Clifton (1980) and Taft (1991) pointed out, articulatory suppression is assumed to disturb meaning integration.

However, the purpose of this experiment was to explore whether articulatory suppression diminished the homophone effect in Japanese sentence acceptability judgment. We found no interaction between articulatory suppression effect and homophone facilitation effect, which could be interpreted that articulatory suppression did not diminish the homophone effect. This result was consistent with many word decision studies in alphabetic languages (e.g., Besner & Davelaar, 1982) and in kanji (Morita & Saito, 2007). Thus, even when the word is embedded in a sentence, its phonology is non-articulatory, which does not go through the articulatory rehearsal process.

These results indicate that articulatory suppression does not interfere in activation of the unseen homophones, and in error recovery process, either. A homophone facilitation effect would be caused by abstract, non-articulatory phonology. In contrast, sentence acceptability judgment itself was interfered by articulatory suppression. These results are consistent with many previous studies of word judgment tasks, which found no interference effect of articulatory suppression on homophone processing. In contrast, speech-like, articulatory phonology would be used in the processing, such as meaning integration (Slowiaczek & Clifton, 1980). We now turn to a discussion about the nature and time-course of this processing.

Processing of Japanese two-kanji compound homophone words in a sentence

Taken together, the results of the current study could be explained well by assuming an activation and verification processing stage. On the activation stage, when participants encounter a foil word, correct word candidates would also be activated from the phonology, orthography, and surrounding context. If the foil was a homophone of the contextually appropriate word, the original word would be rapidly activated. If not, it would be more difficult to choose one candidate. The rapid activation of the original word would result in earlier judgment in the present experiment. In alphabetic writing system, it would be difficult to modify reaction brought from phonological activation of homophone foils. Thus, homophone errors in a sentence or text would tend to be missed more than non-homophone errors (Baron, 1973; Coltheart, Avons, Masterson, & Laxon, 1991; Coltheart, Avons, & Trollope, 1990; Jared et al., 2016; Treiman et al., 1983). The phonology used in this activation process would be abstract, non-articulatory phonology, which does not go through the articulatory rehearsal process. This is consistent with many single word task studies (Baddeley & Lewis, 1981; Besner & Davelaar, 1982; Besner et al., 1981).

This activation would be followed by a verification process. If a potential candidate was activated, participants would verify its orthography with that of the presented foil. The successful error recovery would result in earlier judgment of homophonic sentences than of non-homophonic sentences. In Japanese, it would be easier to modify the reaction to homophone because readers would be sensitive to orthography. Thus, homophone errors in a sentence or text would be recovered easily, because participants would be able to identify the correct word conveniently through foil's homophonic mate than through non-homophone mate. The present study confirmed that this homophone benefit occurred even when the foil was not a pseudohomophone but real homophone word. That would happen because in Japanese each kanji character has its own (multiple) meaning(s) and pronunciation(s). It has been argued that orthography has a relatively larger influence in Japanese kanji word recognition tasks than it does in those using alphabetic writing systems (e.g., Sakuma, et al., 1998; Wydell et al, 1993). Interestingly, error recovery processing does not seem to need articulatory phonology. This error recovery process is assumed to be late phonological processing as mentioned in Feng et al. (2001), but still, the phonology included in this process is non-articulatory, that is, automatically activated phonology.

Although the homophone effect was not affected by articulatory suppression, it does not mean that readers use only non-articulatory phonology in sentence reading. The whole error rate increased under articulatory suppression, which means that sentence acceptability judgment itself was harder under articulatory suppression. Specifically, articulatory suppression had an effect on error rates, but not on reaction times. That is, articulatory suppression had influences on processes in wrongly accepting the sentences with a foil. In order to judge a complex sentence as meaningful one, participants must integrate the meaning, relying on the working memory functioning. Therefore the accuracy rate was affected by the articulatory suppression. Notably, however, such integration processes might not have been necessary when participants correctly rejected the sentences with the foils. To reject the sentence as meaningless one, it would be enough to detect an error (in the written form). This error detection process itself might not be affected by articulatory suppression. Therefore RTs for the correct rejection were not affected by articulatory suppression. This interpretation is in parallel with those claimed in previous studies; that is, articulatory suppression has been shown to interfere in meaning integration (Slowiaczek & Clifton, 1980; Taft, 1991), but not in obtaining general meaning (Baddeley et al., 1981; Levy, 1978).

Our findings also seem to be consistent with previous studies suggesting that a different type of phonology is used depending on processing time course (Baddeley et al., 1981; Besner & Davelaar, 1982; Eiter & Inhoff, 2008; Oppenheim & Dell, 2008). Abstract, non-articulatory phonology is assumed to be included in the rather early stage of processing. In contrast, speech-like, articulatory phonology is assumed to be used in the later stage of sentence processing (Slowiaczek & Clifton, 1980).

In sum, this study confirmed that phonological activation is included in Japanese sentence acceptability judgment and that the direction is toward homophone facilitation. It means that phonological information of homophone helped recover the detected errors. Usually, in sentence acceptability judgment in alphabetic language, homophone errors tend to be missed. However, Japanese readers would be more sensitive to the orthographic information and recovered the error before judgment. It might be because Japanese kanji words particularly have many homophones. More important finding in the present study was that the cause of the homophone facilitation effect was non-articulatory phonology. As some previous studies suggested, articulatory phonology seemed to be included in meaning integration or inference stage. The present study confirmed that the homophone facilitation is emerged in rather early process, which is based on non-articulatory, automatic activated phonology.

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Figures

Fig. 1

Mean response times (ms) in the sentence acceptability judgment in orthographically similar condition. Error bars denote standard error in each condition.

Fig. 2

Mean error rates (%) in the sentence acceptability judgment in orthographically similar condition. Error bars denote standard error in each condition.

Fig. 3

Mean response times (ms) in the sentence acceptability judgment in orthographically dissimilar condition. Error bars denote standard error in each condition.

Fig. 4

Mean error rates (%) in the sentence acceptability judgment in orthographically dissimilar condition. Error bars denote standard error in each condition.

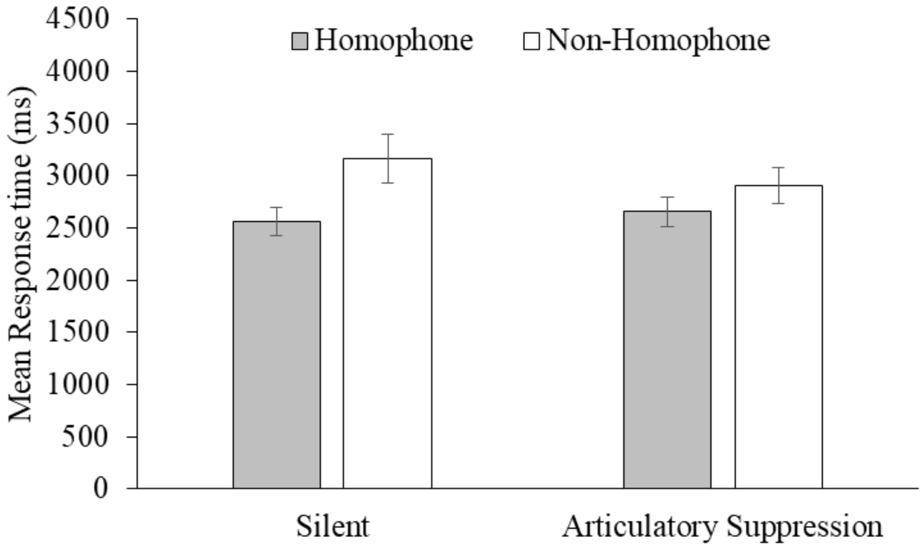
Homophone
Non-Homophone
Mean Response time (ms)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Silent
Articulatory Suppression

Fig. 1

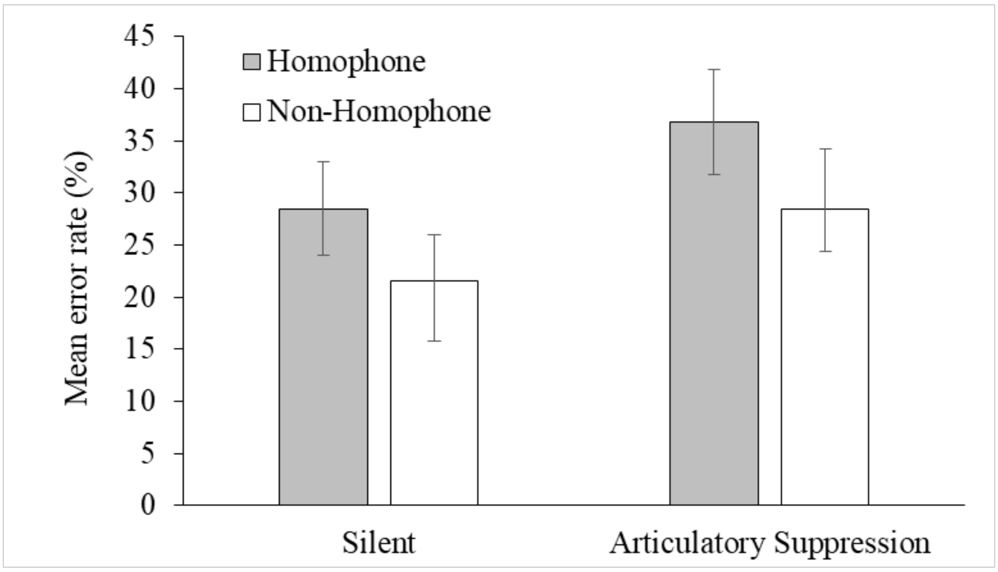
Homophone
Non-Homophone
Mean error rate (%)
45
40
35
30
25
20
15
10
5
0
Silent
Articulatory Suppression

Fig. 2

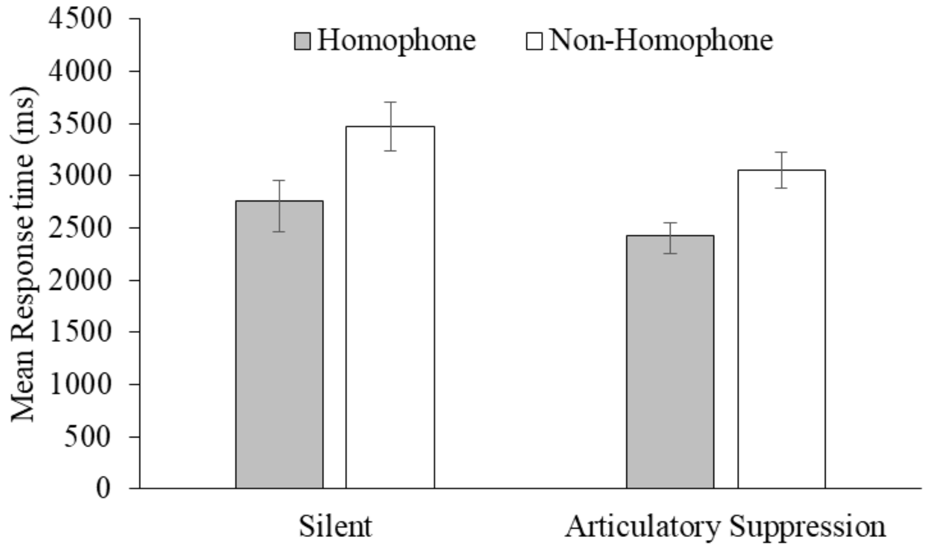
Homophone
Non-Homophone
Mean Response time (ms)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Silent
Articulatory Suppression

Fig. 3

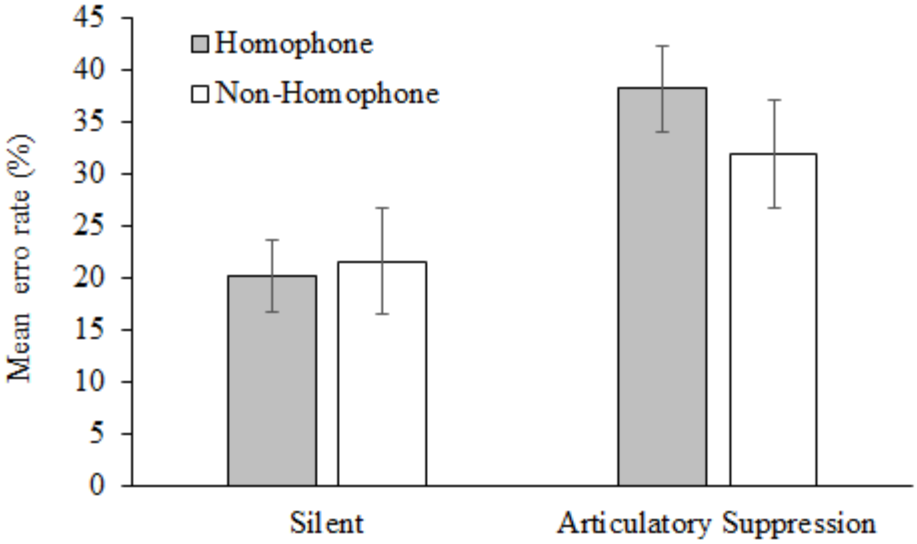
45
40
35
30
25
20
15
10
5
0
Mean erro rate (%)
Homophone
Non-Homophone
Silent
Articulatory Suppression

Fig. 4

Table 1

Example of the stimuli.

	Context	Orthographically similar set		
		Original	Homophone	Non-homophone
Japanese	今後、50%の□□で危機的な問題が起こりうると指摘した。	確率	確立	確実
Pronunciation of a word		/kakuritsu/	/kakuritsu/	/kakujitsu/
English	It was pointed out that the □□ of the occurrence of a a critical issue would be 50%.	probability	establishment	certain
	Context	**Orthographically dissimilar set**		
		Original	**Homophone**	**Non-homophone**
Japanese	この生物は、□□500メートル以上の海域に存在する。	水深	推進	審査
Pronunciation of a word		/suishin/	/suishin/	/shinsa/
English	The life is living at □□ of more than 500 meters of the sea.	depth of the water	promotion	examination

Table 2

Stimulus characteristics of the kanji words

	Orthographically similar foil				Orthographically dissimilar foil			
	Homophone		Non-homophone		Homophone		Non-homophone	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Frequency	9038.94	(18174.91)	8945.50	(19583.36)	23954.50	(29425.89)	23984.06	(29295.38)
Mora	3.56	(0.51)	3.63	(0.50)	3.31	(0.70)	3.31	(0.70)
Number of strokes	17.25	(2.70)	15.31	(5.55)	20.38	(4.01)	16.81	(5.42)
Location in the sentence	12.88	(5.15)	12.88	(5.15)	8.69	(4.87)	8.69	(4.87)